MODELING COMPUTER NETWORK SIMULATION FOR WEB BASED PACS SYSTEM WITH OPNET ITGURU

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Abstract-**Rapid development of teleradiology demands utilization of modern ICT technologies. Considering the rapidness of the development it is obvious that technology deployment have to be quick. Sometimes, implementation of new technology solutions may cause some problems, and usage of the software simulation tools can make this process easier. This paper presents the usage of network simulation software OPNET IT Guru Academic Edition for modeling computer network and its services for teleradiology systems, especially for web based PACS. The modeled system is in the design phase and will be used in the special hospital for lung diseases.**

Keywords **- computer network simulation, medical imaging, OPNET IT Guru, teleradiology, web based PACS**

I. INTRODUCTION

Advances in information technology and telecommunications resulted with development of healthcare and telemedicine and have particularly strong impact in medical imaging and teleradiology as a specific instance of telemedicine. Possible teleradiology scenarios at various geographical scales include local, metropolitan and wide area services involving multimedia communications [1].

This paper presents possible usage of network simulation software OPNET IT Guru Academic Edition [2] for modeling computer network for specific teleradiology system. Teleradiology system model presented in this paper is the part of ongoing project to be implemented at special hospital for lung diseases in Zrenjanin (Serbia). Project goal is design of the teleradiology system to support medical care in special hospital for lung diseases and to provide efficient way for digitalization of X-ray images, and as well as the storage and efficient distribution of the same images.

For the successful completion of the project it is necessary to design the web based PACS system for archiving, distribution and retrieval of medical images. Very important component is computer network infrastructure, which has to be carefully designed in order to support special requirements of the system.

This system has also to be adapted to the Hospital environment as integral part of its information system.

II. SYSTEM DESCRIPTION

The internal organization of Special hospital for lung diseases "Dr Vasa Savic" is significant for the system design. Hospital is organized with central unit located in Zrenjanin and with remote unit located in small village Jasa Tomic. This village is about 25 km northeast from Zrenjanin. Users from these units are interior system users. Hospital in Zrenjanin has 100BaseT Ethernet LAN network with 15 computers. Internet link is realized with xDSL technology with 256 kbps bandwidth. The only access to the Internet

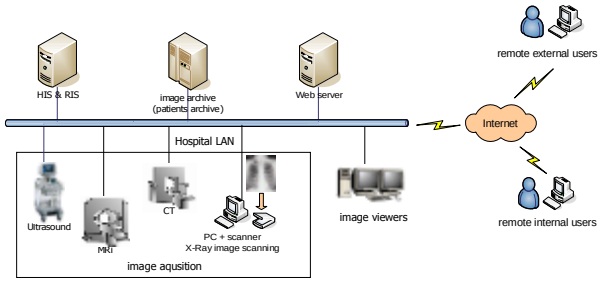

Fig. 1. Architecture of web based PACS system [2]

from the remote unit in Jasa Tomic is via dial-up, with planned upgrade [2].

Besides that, hospital cooperates frequently with general hospital "Dr Djorde Joanovic" in Zrenjanin and with Institute for lung diseases in Sremska Kamenica (50 km away). Users from these hospitals are exterior system users [2].

Considering the infrastructure of the hospital, the best solution for the medical imaging and data exchange is web oriented PACs system "Fig. 1", which will become the part of HIS (Hospital Information System) & RIS (Radiology Information System) of the hospital in the near future [3,4].

The Hospital LAN infrastructure and the system users are presented in "Fig. 2". In this figure are presented only the relevant nodes in the network for the simulation and system functioning.

III. MODELING COMPUTER NETWORK

The Hospital LAN "Fig. 2," has two servers and 5 computers planned to be placed in examination rooms and one xDSL router providing the Internet connections. Connection bandwidth is 256 kbps. Remote users have two types of access. Remote users from internal unit (hospital in Jasa Tomic) have 56k dial-up connection and users from external unit (institute and general hospital) have DSL Internet access via local ISP providers with various

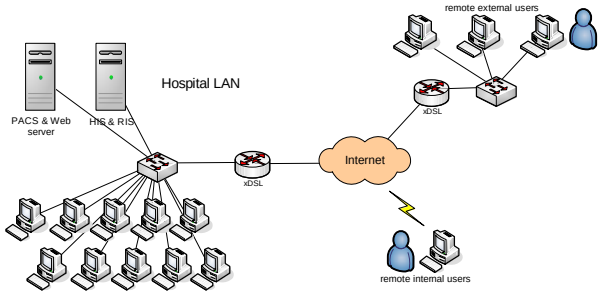

Fig. 2. Hospital LAN infrastructure and teleradiology system users

bandwidths. It has to be pointed out that the bandwidth of the special hospital, as well as the two other hospital are not dedicated only to Web based PACS system. Links are used for the Internet access (web & mail) in everyday work.

Although, there are two servers in the figure, only one (PACS & Web) server is relevant for this simulation. The same is with other workstations, they will be relevant in additional scenarios including other types of traffic, like Internet access, image acquisition etc.

One of the important questions in the process of designing this teleradiology system is the required bandwidth for the network links. It appears, that's really important to simulate network infrastructure and link utilization in order to find most suitable type of services and network infrastructure upgrade if it is necessary.

The network simulation tool used for modeling the web based PACS system and its utilization is OPNET IT Guru Academic Edition [5]. The network model is shown in the "Fig. 3."

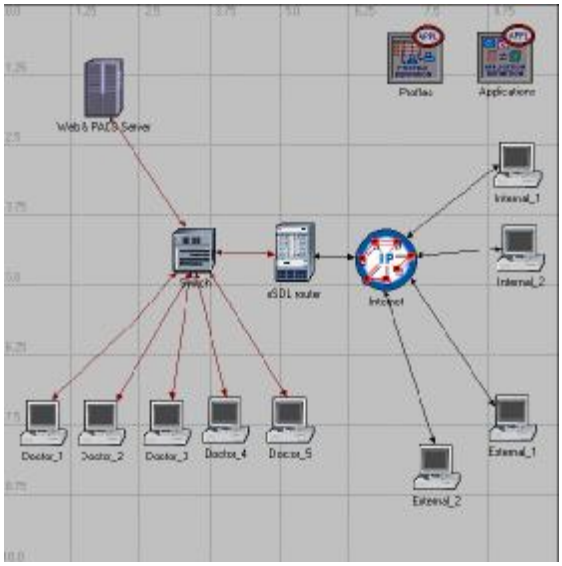

Fig. 3. Web based PACS network simulation in OPNET IT Guru Academic Edition

OPNET IT Guru Academic Edition supports variety of node models. For complete and accurate simulation its important to chose the suitable ones. The node models used for modeling the real nodes are specified in Table I.

TABLE I
NAMES OF THE NODE MODELS USED IN MODELING

N°	System component	Names of the node models
1	Web & PACS server	ethernet_server
2	Computer in hospital	ethernet_wkstn
3	Computer in external units	ppp_wkstn
4	Switch	ethernet_16_switch
5	DSL router	ethernet2_slip8_gtwy
6	Internet	ip32_cloud
7	LAN links	100BaseT
8	Remote user links	ppp_adv
9	Application specification	Application config
10	User profile specification	Profile config

The few required steps in modeling network simulations are server, workstation, link, application and profile configuration. Server configuration requires specification for network-supported services on this particular server, workstation configurations requires specification of user profiles working on hospital computers. User profiles are specification of applications used by various groups of users and specification of traffic caused by those applications. Link specification is based in setting appropriate technology and bandwidth of the link between the nodes.

IV. MODELING TELERADIOLOGY SERVICES

Modeling the services for teleradiology system is performed with application configuration model. Application definition may be specified with editing application configuration model attributes "Fig. 4." Defining the particular application includes a name and a description table that specifies various parameters of an application. An application may have tasks and tasks may have multiple phases. A phase can have many requests and responses. Several example applications are available, e.g. FTP, HTTP,

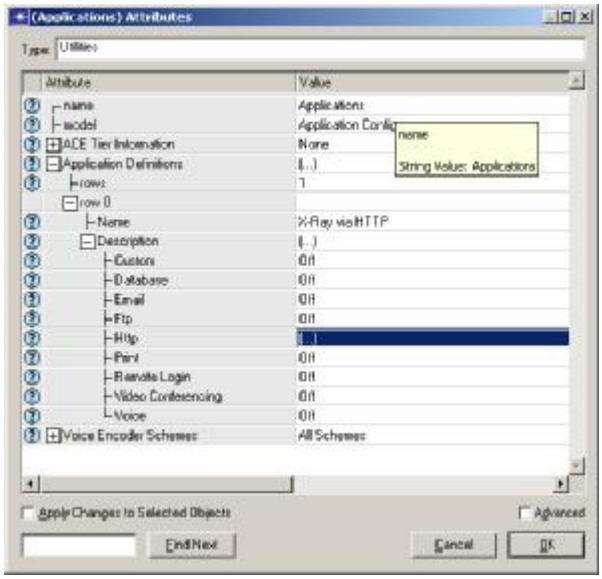

Fig. 4. Application configuration model attributes

and database access with gradation: light, heavy, etc.

Teleradiology system in this particular case has to provide Web based PACS service. That means that required application has to be modeled using http protocol with specific parameters. Application simulates the multiple accesses to the patient records stored at the PACS server during the examination. Patient record has several digitalized X-Ray images with textual patient data. Number of patient images varies from one patient to another, depending of the illness and patient itself. The number of images used for realistic simulation is 1 to 4, images have resolution 1024x1250 with 12 bit color depth and estimated file size from 2 MB to 2.5 MB. Additional patient data are represented as text from 100 to 150 KB. Exact modeling of patient examination and doctors access to the PACS system is presented in "Fig. 5."

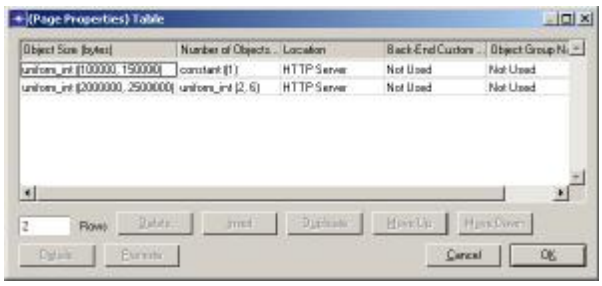

Fig. 5. Modeling patient examination

The name of configured application is X-Ray via HTTP. The first problem was how to describe the medical images retrieval by OPNET IT Guru Academic Edition. OPNET IT Guru Academic Edition supports variety of protocols, but not the DICOM protocol. DICOM (Digital Imaging and COmmunication in Medicine) is international standard for definition and transport of medical information and medical images [6]. Standard was developed in 1992 by ACR-NEMA. The first choice was to the describe this particular situation using FTP protocol because the tests shows that there is no significant differences between those two protocols in transferring the images [7].

Later, in order to create more accurate application specification the file transfer time was compared for HTTP protocol with image browsing traffic type and FTP protocol. The results are almost the same, so in the further work is used HTTP protocol because its more realistic traffic model of web based PACS system. Using HTTP protocol enables combination of medical images with textual data representing the additional patient record. Attributes of X-Ray via HTTP application are specified in Table II. One of the most important parameters is parameter Page Interarrival Time (Table II, N° 2). It is time between two page retrievals, that means between two medical examinations in this case. Parameter value is set to uniform in the interval from 300 to 1200 seconds. These parameter settings can be applied for doctor's examination performed in Special hospital only. For other doctor's examinations, e.g. for doctor's examination in remote units of the hospital, parameter values may be different. Those values may be smaller if the frequency of examination is smaller and vice versa.

TABLE II
APPLICATION ATTRIBUTES

N°	Attribute	Value
1	HTTP Specification	HTTP 1.1
2	Page Interarrival Time (seconds)	uniform (300,1200)
3	Page Properties	...
4	Server Selection	... (default)
5	RSVP Parameters	None
6	Type Of Service	Best Effort (0)

The other important parameter is presented in Table III. It's a web page property, enabling modeling of a web page context. Web page of PACS system has to types of information. First, it's textual patient data (Table III, item N°1), which varies from 100 to 150 KB, and it can be changed if it is necessary. Second data types are medical images. Number of those images (Table III, item N°2) can vary from examination to examination, so the parameter value is set to uniform_int(1,4). Also, the size of images can also vary and the parameter is set to uniform_int (2000000,2500000) according to estimated image size, but can be changed.

TABLE III
PAGE PROPERTIES

N°	Object Size	Number of Objects
1	uniform_int (100000,150000)	constant (1)
2	uniform_int (2000000,2500000)	uniform_int (1,4)

After setting up the application profile, the next step is profile configuration. A profile describes user activity over a period of time and consists of many different applications. The created profiles have to be attached to the particular object (e.g. workstations) to generate traffic. In this case it is enough to configure one profile called Examination for examination performed in hospital and other profile for examination in every other remote unit (e.g. Examination_Internal_56k, Examination_External_128k, Examination_External_256k). The major profile is Examination and it helps us to monitor the network performance during the one shift in the hospital. Other profiles have smaller frequency, because doctors in these units have considerably lower need for accessing patient records and digital images. Other profiles also help us to monitor Internet link utilization and to define appropriate bandwidth.

V. MEASURING THE NETWORK PERFORMANCE

Finally, after defining types of services available on the server, and after attaching the profiles to the appropriate workstations we may start the simulation. Simulation is set to 8 hours duration to simulate 8-hour shift. Monitored statistic in this paper is mainly the link statistic.

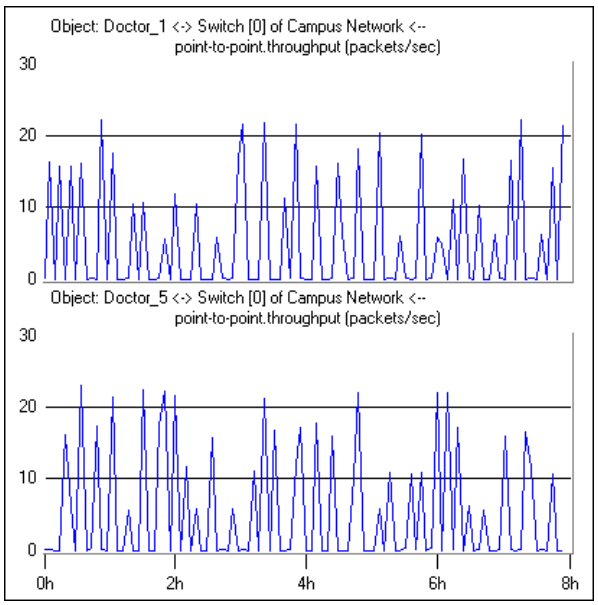

Fig. 6. Examination activity

The workstation activity is presented in the "Fig. 6". This figure shows activity on two workstations and slightly different intervals of web access and image retrievals. First computer have 32 PACS access randomly created with profile configuration, and the other one has 31 accesses. Each peek on the graph represents one PACS access. The frequency of examination may be changed if it is required.

Other important results are link utilization. In the "Fig. 7." is presented the link utilization of hospital Internet link.

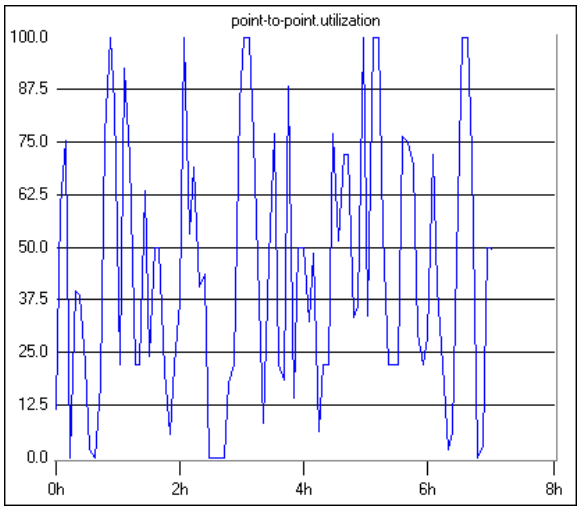

Fig. 7. DSL link utilization

VI. Conclusion

Using network simulation tool for modeling and testing computer network infrastructure supporting the teleradiology services is important. It makes easier the process of planning and designing the required network infrastructure, and designing of required network services as well.

This modeling have much greater importance in the environment where non similar systems exists and in environments where particular systems and services have to be adopted to the existing infrastructure or where the existing infrastructure have to be adopted to the teleradiology system.

The other importance of the simulation tool usage is in possibility to simulate large-scale WAN networks and very distributed system environments, in order to predict bandwidth and technology needs.

The simulation tool used in this case is OPNET IT Guru Academic Edition. It seems very applicable for this case, especially for designing Web based PACS services, but it also can be useful for simulating other medical imaging services, such as digitized computed tomography (CT), ultrasound (US), magnetic resonance imaging (MRI), nuclear medicine (NM), general angiography, etc. especially in wide-area services [7,8].

In the future this simulation can be expanded with other network traffic (web, e-mail, FTP) and with image acquisition workstation uploading medical images to the server. Also, the comparison of simulation results and measurements of the real system performance can be done in the future, after the implementation of the system.

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